Dynamic Bank Capital Requirements

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Motivation

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  - risk-based capital requirements
  - credit supply is overly pro-cyclical

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  - risk-based capital requirements
  - credit supply is overly pro-cyclical
- Basel III 2010:
  - countercyclical capital buffers (CCyB)
    - additional layer of capital between 0% and 2.5%
    - effectively, time-varying capital charges
  - few trials within EU nations

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- Key anchor: "credit gap" (*deviation of credit-to-GDP ratio from its trend*)

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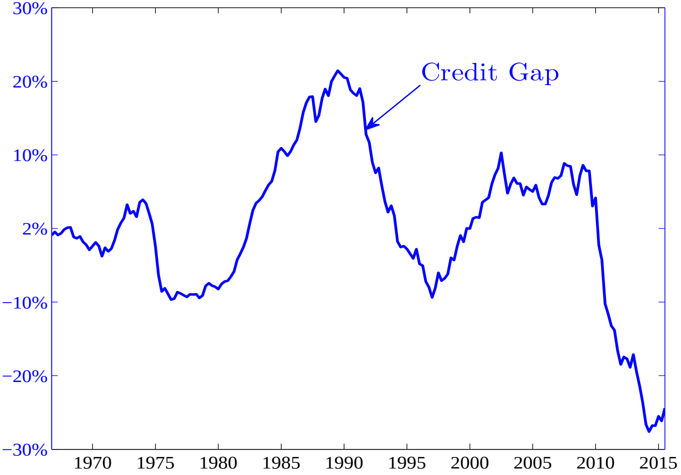

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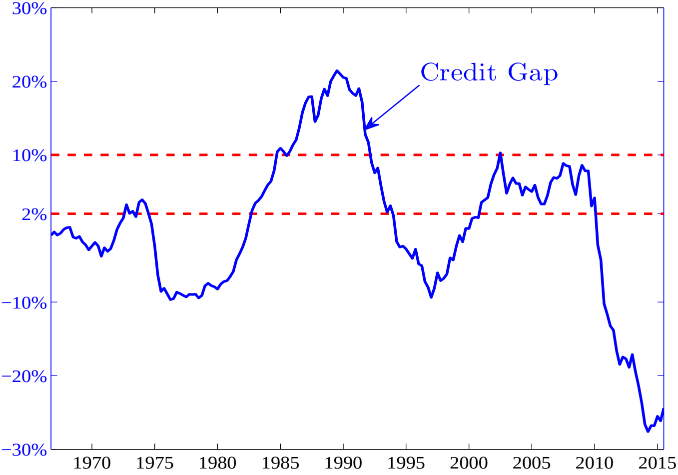

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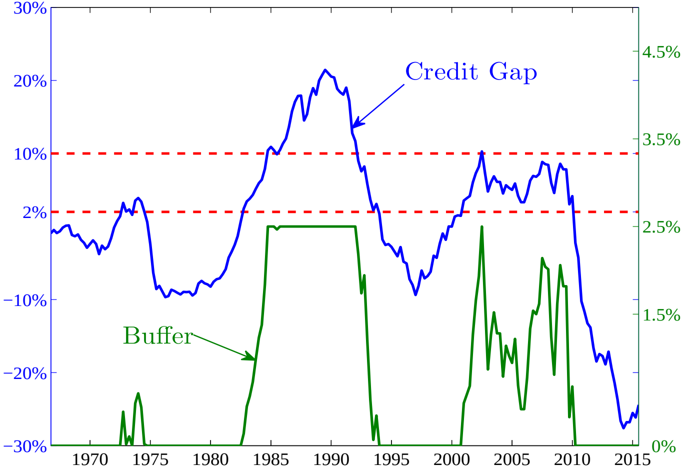

Main Mechanism

Optimal capital regulation over the cycle

Frictions:

- Government bailouts + Limited liability
  - Risk-shifting motive
  - Excessive lending

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$\Rightarrow$ ***Procyclical capital regulation - optimal scheme in Ramsey equilibrium***

Contribution

Theoretical model:

- Characterize optimal state-dependent capital requirements
- Document novel trade-offs associated with dynamic policies:
    - Procyclical risk-shifting
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Quantitative analysis:

- Solve for optimal Ramsey policy
  - Mostly varies between 4% and 6%
  - Centered around 5%
- Assess welfare implications
- Key cyclical determinants: credit gap, GDP growth and liquidity premium
  - Credit gap used alone falls short

Baseline Model

Model Setup

Baseline Model - Setup (1/8)

Continuum of $[0, 1]$ ex-ante identical **banks**:

- Access to decreasing returns to scale technology

$$y_{j,t} = e^{\omega_{j,t}+a_t} l_{j,t}^{\alpha}$$

  - a_t – aggregate productivity shock

$$a_t = (1-\rho_a)\,\bar{a} + \rho_a a_{t-1} + \sigma_a \epsilon_t, \qquad \epsilon_t \sim iid\ \mathcal{N}(0,1)$$

  - $\omega_{j,t}$ – idiosyncratic shock, *i.i.d* across time and across banks

$$\omega_{j,t} = -\frac{1}{2}\sigma_\omega^2 + \sigma_\omega \varepsilon_{j,t}, \qquad \varepsilon_{j,t} \sim iid\ \mathcal{N}(0,1)$$

Baseline Model - Setup (2/8)

$t-1$ $\qquad\qquad$ t

Bank j:

- issues loans $l_{j,t}$
- financed either with equity or deposits $l_{j,t} = n_{j,t} + d_{j,t}$

- enters with balance sheet

$l_{j,t}$	$n_{j,t}$
	$d_{j,t}$

- realized profits

$$\pi_{j,t} = e^{\omega_{j,t}+a_t} l_{j,t}^{\alpha} - (R_{d,t} - 1)\, d_{j,t}$$

- receives bailout transfer if

$$\pi_{j,t} + n_{j,t} < 0 \quad \Leftrightarrow \quad \omega_{j,t} < \omega_t^*$$

- pays dividends/issues equity $z_{j,t}$

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Baseline Model - Setup (3/8)

- Net worth available at end of period t (going into period $t+1$):

$$n_{j,t+1} = max\left\{\pi_{j,t} + n_{j,t}, 0\right\} - z_{j,t}$$

- Subject to capital requirement, ζ_t:

$$n_{j,t+1} \geq \zeta_t l_{j,t+1}$$

Baseline Model - Setup (4/8)

Bank j decides how many loans to issue and makes leverage choice:

$$\begin{aligned}
& \max_{l_{j,t+\mathbf{1}}, d_{j,t+\mathbf{1}}, n_{j,t+\mathbf{1}}} E\left[\sum_{t=0}^{\infty} \beta^t z_{j,t}\right] \\
s.t. \quad & n_{j,t+1} = max\left\{e^{\omega_{j,t}+a_t} l_{j,t}^{\alpha} - R_{d,t} d_{j,t}, 0\right\} - z_{j,t}, \\
& l_{j,t+1} = n_{j,t+1} + d_{j,t+1}, \\
& n_{j,t+1} \geq \zeta_t l_{j,t+1}, \\
& l_{j,0},\ d_{j,0} \quad given.
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- Equilibrium is **symmetric**:

$$l_{j,t+1} = L_{t+1}, \quad \forall j \in \Omega$$

Baseline Model - Setup (5/8)

Household sector:

- Continuum of $[0, 1]$ identical households
- Two types of members:
  - Savers: supply deposits
  - Bankers: manage financial intermediaries
- Perfect consumption insurance

Baseline Model - Setup (6/8)

Household solves:

$$\max_{C_t, D_{t+1}} E\left[\sum_{t=0}^{\infty} \beta^t \left(C_t + \frac{D_{t+1}^{1-\eta}}{1-\eta}\right)\right], \qquad 0 < \eta < 1$$

$$s.t. \qquad C_t = R_{d,t} D_t - D_{t+1} + Z_t - T_t,$$

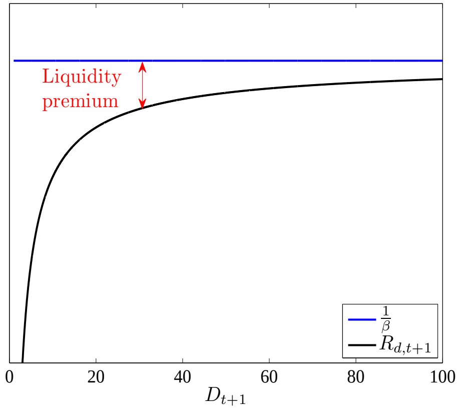
where C_t, D_{t+1} - family consumption and deposits supply

- Preference for holding liquidity
- Bank deposits subject to government guarantees
  - Rate of return on deposits $R_{d,t+1} \Rightarrow$ safe
- Owners of banks
  - Net proceeds Z_t
- Subject to lump-sum tax T_t

Baseline Model - Setup (7/8)

- FOC deliver discount on deposits rate

$$R_{d,t+1} = \frac{1}{\beta} - \frac{1}{\beta} D_{t+1}^{-\eta}$$



Baseline Model - Setup (8/8)

Government:

- Provides bailout subsidies
- Balanced budget rule:

$$T_t = \int_0^1 max\left\{R_{d,t}d_{j,t} - e^{\omega_{j,t}+a_t}l_{j,t}^{\alpha}, 0\right\} dj$$

Social Optimum

Social Optimum: First Best Allocation (1/3)

Social planner solves:

$$\max_{C_t, L_{t+1}, D_{t+1} \leq L_{t+1}} E\left[\sum_{t=0}^{\infty} \beta^t \left(C_t + \frac{D_{t+1}^{1-\eta}}{1-\eta} \right)\right]$$

$$s.t. \qquad C_t + L_{t+1} = e^{a_t} L_t^{\alpha}$$

First-best allocation:

- Bank's optimal finance policy:

$$D_{t+1}^{FB} = L_{t+1}^{FB} \qquad N_{t+1}^{FB} = 0$$

- Optimal level of bank lending, L_{t+1}^{FB}:

$$E_t\left[R_{l,t+1}^{FB}\right] = \underbrace{E_t\left[\alpha e^{a_{t+1}} \left(L_{t+1}^{FB}\right)^{\alpha-1}\right]}_{\text{Marginal benefit}} = \underbrace{\frac{1}{\beta} - \frac{1}{\beta}\left(L_{t+1}^{FB}\right)^{-\eta}}_{\text{Marginal cost}} = R_{d,t+1}^{FB}$$

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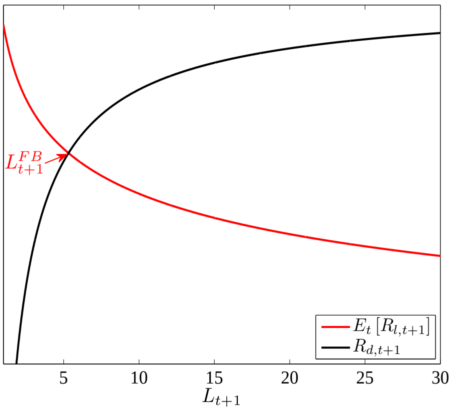
Social Optimum: First Best Allocation (2/3)

- Optimal level of bank lending, L^{FB}_{t+1}:

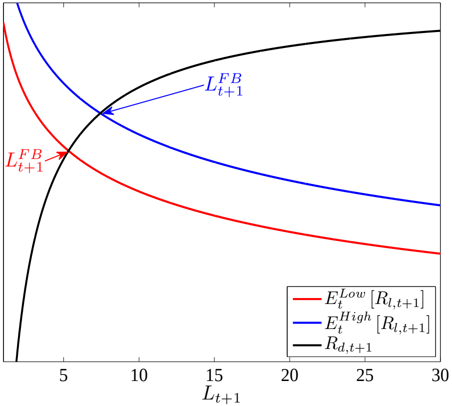
$$E_t\left[R^{FB}_{l,t+1}\right] = R^{FB}_{d,t+1}$$



Social Optimum: First Best Allocation (3/3)

- Optimal level of bank lending, L_{t+1}^{FB}, is procyclical:

$$\frac{\partial L_{t+1}^{FB}}{\partial a_t} > 0$$



Competitive Equilibrium

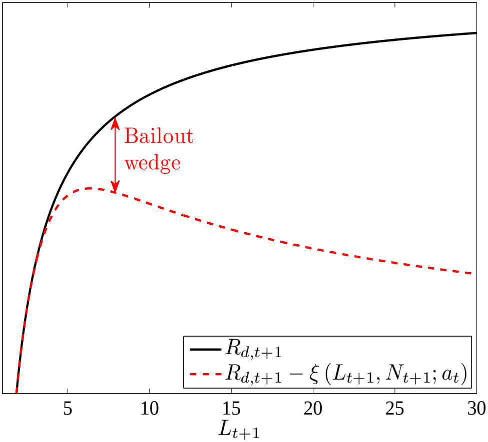
No Capital Regulation

Competitive Equilibrium: No Capital Requirement (1/4)

- Bailout wedge in bank's borrowing cost

$$\xi\left(L_{t+1}, N_{t+1}; a_t\right) = E_t\left[\int_0^{\omega^*_{t+1}} \left(R_{d,t+1} - e^{\omega} R_{l,t+1}\right) dF\left(\omega\right)\right]$$

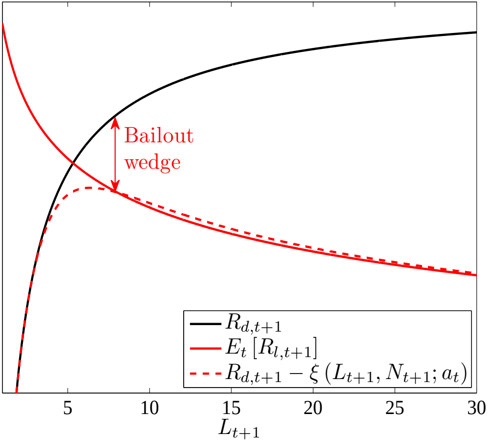
  - Increasing in bank lending L_{t+1}



Competitive Equilibrium: No Capital Requirement (2/4)

- Excessive lending in competitive equilibrium:

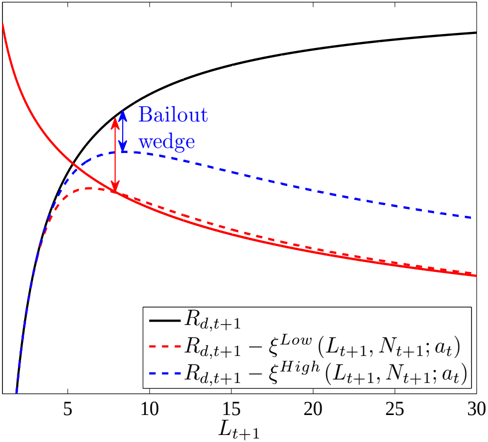
$$L_{t+1}^{CE} > L_{t+1}^{FB}$$



Competitive Equilibrium: No Capital Requirement (3/4)

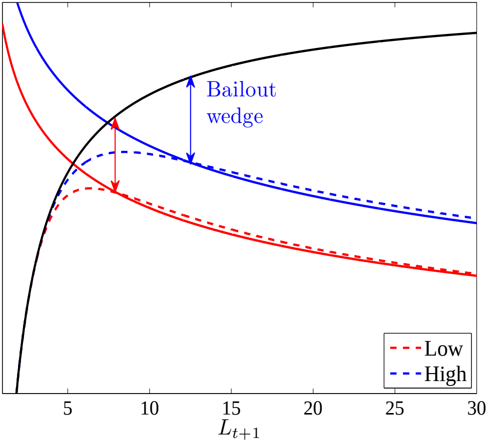
- Bailout wedge is decreasing in aggregate productivity a_t

$$\xi\left(L_{t+1}, N_{t+1}; a_t\right) = E_t\left[\int_0^{\omega^*_{t+1}} \left(R_{d,t+1} - e^{\omega} R_{l,t+1}\right) dF\left(\omega\right)\right]$$



Competitive Equilibrium: No Capital Requirement (4/4)

- Expected government bailout subsidies
  - $\ominus$ decreasing in a_t
  - $\oplus$ increasing in bank lending
- Excessive lending is procyclical iff $-\bar{\xi}_a < \frac{\partial \xi(\cdot)}{\partial a_t} < 0$



Competitive Equilibrium

With Capital Regulation

Competitive Equilibrium: With Capital Requirement (1/2)

Bank sector:

- Subject to capital requirement, ζ_t:

$$N_{t+1} \geq \zeta_t L_{t+1}$$

- Equity is more expensive than debt:

  $\Rightarrow$ banks forgo government subsidy

  $\Rightarrow$ banks give up discount on interest rate

- Binding capital constraint:

$$N_{t+1}^{CE} = \zeta_t L_{t+1}^{CE} \qquad \& \qquad D_{t+1}^{CE} = (1 - \zeta_t) L_{t+1}^{CE}$$

Competitive Equilibrium: With Capital Requirement (2/2)

Bank cost of lending:

$$E_t\left[R^{CE}_{l,t+1}\right] = R^{CE}_{d,t+1} + \underbrace{\zeta_t\left(\frac{1}{\beta} - R^{CE}_{d,t+1}\right)}_{\textit{Liquidity premium}} - \left(\xi\left(L^{CE}_{t+1}, N^{CE}_{t+1}; a_t\right) - \underbrace{\zeta_t E_t\left[\int_0^{\omega^*_{t+1}} R^{CE}_{d,t+1}\, dF(\omega)\right]}_{\textit{Government transfer}}\right)$$

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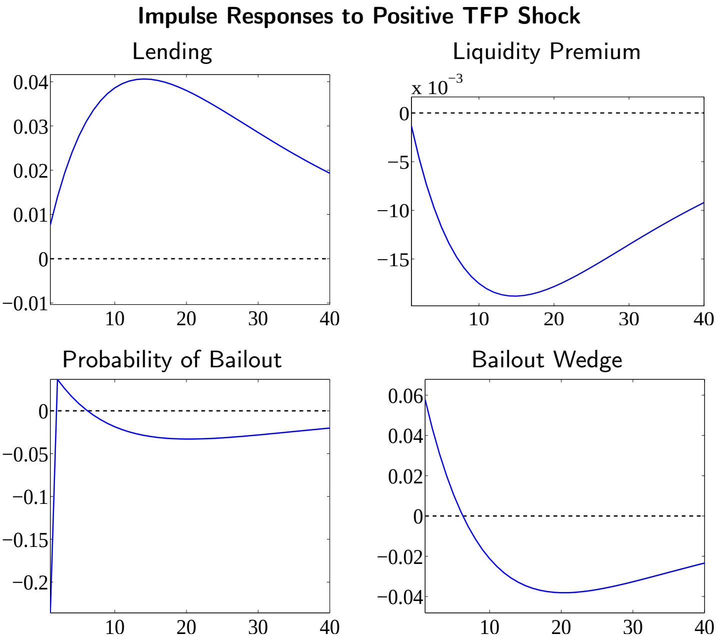
- Increasing with tightening of capital requirements
- Regulator's goal:
  - Dampen risk-shifting cost without excessive increase in liquidity cost

Quantitative Assessment

Configuration of Model Parameters

Description	Symbol	Value	Source/Target
Subjective Discount Factor	β	0.975	Standard
Risk Aversion Coefficient	γ	1.000	Standard
Elasticity of Deposits and Consumption	η	1.200	St.dev. of debt-consumption ratio
Deposits Weight	χ	0.010	Average liquidity premium
Firm Capital Share	α_f	0.355	Capital-output ratio
Firm Operating Cost	o_f	0.055	St.dev. of investment-capital ratio
Bank Capital Share	α_b	0.780	Capital-output ratio
Bank Operating Cost	o_b	0.065	Profit-to-loan ratio
Bank Output Weight	$\bar{a}_b$	-1.35	Capital ratio in two sectors
Capital Adequacy Ratio	$\bar{\zeta}$	0.073	Average leverage ratio
Depreciation Rate	δ	0.075	Investment-capital ratio
Persistence of Productivity Schock	ρ_a	0.95	Process for Solow residuals
Std of Productivity Schock	σ_a	0.020	
Std of Idiosyncratic Shock	σ_ω	0.335	Bailout rate
Dispersion of Idiosyncratic Volatility	ν	0.500	Idiosyncratic volatility dispersion

Risk-Shifting and Liquidity during Expansions



Optimal Policy Rule

Ramsey Capital Requirement

- Lending capital requirement, ζ_t^L:

$$L_{t+1}^{\zeta^L} = L_{t+1}^{FB} \qquad \& \qquad D_{t+1}^{\zeta^L} < D_{t+1}^{FB}$$

- Liquidity capital requirement, ζ_t^D:

$$D_{t+1}^{\zeta^D} = D_{t+1}^{FB} \qquad \& \qquad L_{t+1}^{\zeta^D} > L_{t+1}^{FB}$$

- **Ramsey capital requirement** trades off reduced inefficient lending with reduced liquidity provision

Details

Optimal Policy Rule

- Ramsey capital requirement is defined by:

$$\zeta_t^* = \zeta\left(\tilde{S}_t, \tilde{S}_{t-1}\right) \approx 5\% + 0.1\% \times \left(\tilde{l}_t - \tilde{y}_t\right) + 0.7\% \times \tilde{y}_t \quad \left[R^2 = 99.99\%\right]$$

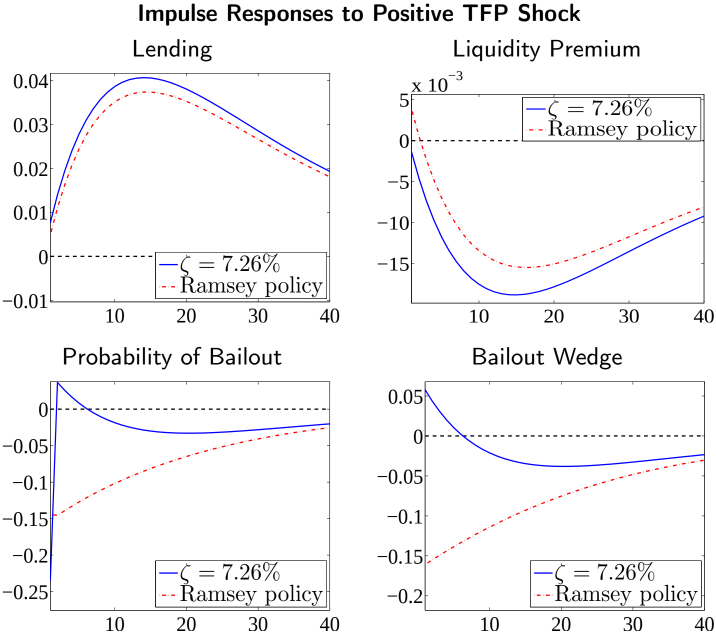
with

$$\tilde{S}_t = (S_t - S_{ss})\,/\sigma_S \qquad \& \qquad S_t = \{\zeta_{t-1}, L_t, K_{f,t}, a_t\}$$

  - Fluctuates mostly between 4% and 6%
  - One standard deviation increase in credit gap increases ζ^* by 0.1%

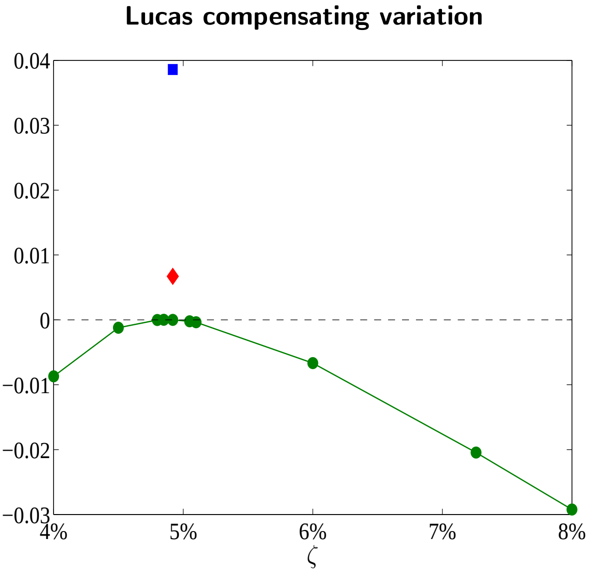
- Credit gap as solely indicator $\left[R^2 = 13.66\%\right]$

Model Dynamics in Ramsey Economy



Welfare Analysis

Welfare Implications of Dynamic Policies



■ - Ramsey policy, ♦ - policy solely based on credit gap, ● - fixed capital ratios

Model with Liquidity Shocks

- **Liquidity shocks** to household preference for liquidity

$$log\left(\chi_t\right) = \left(1-\rho_\chi\right)\bar{\chi} + \rho_\chi log\left(\chi_{t-1}\right) + \sigma_\chi \varepsilon_t, \qquad \varepsilon_t \sim iid\ \mathcal{N}\left(0,1\right)$$

- Implications:

$$\zeta_t^* \approx 5\% + 0.1\% \times \left(\tilde{l}_t - \tilde{y}_t\right) + 0.7\% \times \tilde{y}_t \qquad \left[R^2 = 91.07\%\right]$$

$$\zeta_t^* \approx 5\% + 0.1\% \times \left(\tilde{l}_t - \tilde{y}_t\right) + 0.7\% \times \tilde{y}_t - 0.1\% \times \tilde{lp}_t \qquad \left[R^2 = 97.66\%\right]$$

Conclusions

- Welfare gain from dynamic policies is large
- Procyclical capital requirements
  - Prevent inefficient lending during expansions
  - Do not restrict bank lending and liquidity provision during recessions
- Ramsey policy fluctuates between 4% and 6%
- Key cyclical indicators: credit gap, GDP growth and liquidity premium
  - Optimal policy significantly outperforms Basel proposed policy

Quantitative Model

Production sector

- Two sectors:
  (i) Bank-dependent
  (ii) Bank-independent
- Multiperiod loans $\delta < 1$
  - loans = capital accumulated by bank-dependent borrowers
- Countercyclical dispersion of bank-specific shocks: $\sigma_\omega(a_t) = \sigma_\omega e^{-\nu a_t}$
- Operating costs

Household sector

- CRRA utility defined over consumption and deposits according to CES aggregator

$$v(C_t, D_{t+1}) = \left(C_t^{\frac{\eta-1}{\eta}} + \chi D_{t+1}^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}}$$

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Quantitative Model

Production sector

- Two sectors:
  - (i) Bank-dependent
  - (ii) Bank-independent
- Multiperiod loans $\delta < 1$
  - loans = capital accumulated by bank-dependent borrowers
- Countercyclical dispersion of bank-specific shocks: $\sigma_\omega(a_t) = \sigma_\omega e^{-\nu a_t}$
- Operating costs

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Quantitative Model - Production Sector

Production sector

- **Bank-dependent**
  - Production technology

$$e^{\omega_{j,t}+\bar{a}_b+a_t} l_{j,t}^{\alpha_b}$$

    - ★ Dispersion of *iid* shocks $\sigma_\omega(a_t) = \sigma_\omega e^{-\nu a_t}$
  - Capital accumulation

$$\underbrace{K_{b,t+1}}_{L_{t+1}} = (1-\delta)\underbrace{K_{b,t}}_{L_t} + I_{b,t}$$

  - Operating cost $o_b > 0$
- **Bank-independent**
  - Production technology

$$e^{a_t} K_{f,t}^{\alpha_f}$$

  - Rental rate $R_{k,t}$

$$R_{k,t} = \alpha_f e^{a_t} K_{f,t}^{\alpha_f - 1}$$

  - Capital accumulation

$$K_{f,t+1} = (1-\delta) K_{f,t} + I_{f,t}.$$

  - Operating cost $o_f > 0$

Quantitative Model - Household Sector

Household sector:

$$\max_{C_t, D_{t+1}} E\left[\sum_{t=0}^{\infty} \beta^t \frac{v\left(C_t, D_{t+1}\right)^{1-\gamma} - 1}{1-\gamma}\right]$$

$$s.t. \qquad v\left(C_t, D_{t+1}\right) = \left(C_t^{\frac{\eta-1}{\eta}} + \chi D_{t+1}^{\frac{\eta-1}{\eta}}\right)^{\frac{\eta}{\eta-1}}, \quad \eta > 1$$

- Rate of return on deposits:

$$E_t\left[M_{t,t+1} R_{d,t+1}\right] = 1 - \chi\left(\frac{D_{t+1}}{C_t}\right)^{-\frac{1}{\eta}}$$

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Mapping Model to Data (1/2)

Output, investment, stock of capital *(Financial Accounts of U.S., NIPA)***:**

- Bank-dependent sector:
  - (i) Households and Nonprofit Institutions Serving Households
  - (ii) Nonfinancial Noncorporate Business
- Bank-independent sector:
  - (i) Nonfinancial Corporate Business
  - (ii) Federal, State and Local Governments

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Mapping Model to Data (2/2)

Bank specific data:

- Capital adequacy ratio and bank profits *(FDIC Aggregate Time Series)*
- Bailout rate *(FDIC Bank Fail List)*
- Bank debt *(Financial Accounts of U.S.)*:
  - deposits plus other forms of short-term debt net of Treasury holdings and liquid assets (Krishnamurthy, Vissing-Jorgensen (2015))
- Liquidity premium *(Federal Reserve Selected Interest Rates)*:
  - spread between 3 Month Commercial Paper and 3 Month TBill

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Benchmark Calibration

First Aggregate Moments

	Data	Model Mean	Model 2.5%	Model 97.5%
		Aggregate Sector		
Capital-Output, K/Y	3.03	2.99	2.86	3.13
Investment-Capital, I/K	0.07	0.08	0.07	0.08
		Market Fraction		
Capital Weight, K_b/K	0.46	0.45	0.40	0.51
Output Weight, Y_b/Y	0.28	0.28	0.23	0.33
		Banking Sector		
Capital-Output, K_b/Y_b	4.96	4.87	4.79	4.94
Investment-Capital, I_b/K_b	0.05	0.08	0.07	0.09
Capital Adequacy Ratio, $N/L, \%$	7.26	7.26	7.26	7.26
Profit-Lending, π/L	0.04	0.05	0.05	0.05
Liquidity Premium, $R_f - R_d, \%$	0.57	0.56	0.46	0.65
Bailout Rate, %	0.76	0.79	0.56	1.06
		Bank-Independent Sector		
Capital-Output, K_f/Y_f	2.29	2.28	2.23	2.33
Investment-Capital, I_f/K_f	0.09	0.08	0.07	0.08

Benchmark Calibration

Second Aggregate Moments

	Data	Model Mean	Model 2.5%	Model 97.5%
		Aggregate Sector		
Consumption, $\sigma(\Delta c)$	1.28	0.83	0.61	1.14
Output, $\sigma(\Delta y)$	2.00	2.02	1.66	2.41
Investment, $\sigma(\Delta i)$	4.36	7.16	5.96	8.47
		Banking Sector		
Output, $\sigma(\Delta y_b)$	2.54	2.22	1.71	2.84
Investment, $\sigma(\Delta i_b)$	9.28	12.49	10.40	14.89
Lending, $\sigma(\Delta l)$	2.60	1.53	0.97	2.32
Debt-Consumption Ratio, $\sigma(\Delta d - \Delta c)$	3.67	0.79	0.47	1.25
Profits, $\sigma(\Delta \pi)$	13.59	10.58	8.44	13.09
		Bank-Independent Sector		
Output, $\sigma(\Delta y_f)$	2.07	2.00	1.67	2.38
Investment, $\sigma(\Delta i_f)$	3.84	3.09	2.54	3.70
Liquidity Premium, $\sigma(R_f - R_d)$	0.35	0.03	0.01	0.07

Benchmark Calibration

Business Cycle Correlations

	Data	Model Mean	Model 2.5%	Model 97.5%
		Aggregate Sector		
Consumption, $\rho(\Delta c, \Delta y)$	0.77	0.89	0.86	0.93
Investment, $\rho(\Delta i, \Delta y)$	0.84	0.97	0.93	0.99
		Banking Sector		
Output, $\rho(\Delta y_b, \Delta y)$	0.82	0.95	0.93	0.97
Investment, $\rho(\Delta i_b, \Delta y)$	0.70	0.95	0.91	0.97
Lending, $\rho(\Delta l, \Delta y)$	0.47	0.69	0.64	0.74
Deposits, $\rho(\Delta d - \Delta c, \Delta y)$	0.54	0.37	0.22	0.55
Profits, $\rho(\Delta \pi, \Delta y)$	0.15	0.79	0.74	0.84
Liquidity Premium, $\rho(R_f - R_d, \Delta y)$	-0.21	0.04	-0.32	0.38
		Bank-Independent Sector		
Output, $\rho(\Delta y_f, \Delta y)$	0.96	0.99	0.98	1.00
Investment, $\rho(\Delta i_f, \Delta y)$	0.59	0.94	0.92	0.95

Ramsey Problem

Ramsey planner maximizes lifetime utility of households subject to implementability conditions:

$$\left\{C_t^*, L_{t+1}^*, D_{t+1}^*, K_{f,t+1}^*\right\} = argmax\ E\left[\sum_{t=0}^{\infty} \beta^t u\left(C_t, D_{t+1}\right)\right]$$

$$\begin{aligned} s.t. \quad & budget\ constraint\ \&\ FOCs\ of\ households \\ & balance\ sheet\ constraint\ \&\ FOCs\ of\ banks \\ & FOCs\ of\ bank-independent\ firms \\ & resource\ constraint \end{aligned}$$

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Ramsey Problem

Ramsey planner solves:

$$\left\{C_t^*, L_{t+1}^*, D_{t+1}^*, K_{f,t+1}^*\right\} = argmax\ E\left[\sum_{t=0}^{\infty}\beta^t u\left(C_t, D_{t+1}\right)\right]$$

$$\begin{aligned}
s.t. \qquad & C_t = R_{d,t}D_t - D_{t+1} + Z_t - T_t + R_{k,t}K_{f,t} - I_{f,t} - o_f K_{f,t} \\
& E_t\left[M_{t,t+1}R_{d,t+1}\right] = 1 - \chi\left(\frac{D_{t+1}}{C_t}\right)^{-\frac{1}{\eta}} \\
& E_t\left[M_{t,t+1}\tilde{R}_{l,t+1}\right] = \theta_t - \tilde{\xi}_t \\
& L_{t+1} = N_{t+1} + D_{t+1} \\
& E_t\left[M_{t,t+1}\tilde{R}_{k,t+1}\right] = 1 \\
& C_t + I_t + o_b L_t + o_f K_{f,t} = Y_t
\end{aligned}$$

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